Acta Polytechnica **54**(1):22–27, 2014
doi:10.14311/AP.2014.54.0022

available online at http://ojs.cvut.cz/ojs/index.php/ap

SIZE ANALYSIS OF SOLID PARITCLES AT THE EXPERIMENTAL DEVICE FOR MULTI-STAGE BIOMASS COMBUSTION

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Abstract. This paper presents the results of an analysis of ash content particles produced in biomass combustion at an experimental device. The main parts of the device are: the water heater, the gasifying chamber, the air preheater, and the fuel feeder. This device can be modified for combustion in an oxygen-enriched atmosphere. Sawdust and wood chips were used as fuel, and were laid loosely into the device. Ash specimens were extracted from various parts of the device. For the measurements themselves, we used the Analysette 22 MicroTec Plus universal laser diffraction device manufactured by the Fritch Company, in the size range from 0.08 µm to 2000 µm. The device utilizes laser diffraction for particle size analysis.

Keywords: laser diffraction, emission, biomass combustion, exhaust pipe.

1. Introduction

It is essential to know the size of particles in many fields of industry and science, e.g. material science, medicine, biology, and the power industry. The size of a particle [4] is considered to be the diameter (radius) of a perfectly spherical particle. For any other shape of a particle, the size parameter is its length, which must be defined according to the measurement method that is used.

Laser diffraction [3] is currently the most widely-used method for particle size measurements. The physical principle that is utilized has been known since the beginning of the 20th century, but this method was developed only after the invention of suitable laser devices and computers. Nowadays this method is replacing other particle size measurement methods, due to its flexibility and readiness.

Figure 1. Laser analyser.

2. Description of the equipment

The ANALYSETTE 22 MicroTec plus (Fig. 1) is a universal analysing device for particle measurement of suspensions, emulsions and solid matter with laser diffraction. The device consists of a central measuring unit and a dispersion module. There are two semi-conductor lasers in the central measuring unit, each with output of 7 mW and a wavelength of 532 nm and 940 nm, respectively. The measuring range is from 0.008 µm up to 2000 µm. The dispersion unit is an ultrasound water bath (organic fluids or saturated inorganic salt solutions can be used on a short-term basis) with maximum output of 50 W and frequency of 40 kHz. Any fluid comes into contact with chemically stable materials only [2].

The extent of laser beam diffraction and the way it is reflected depends on the size and the optical attributes of each particle that the beam strikes. The

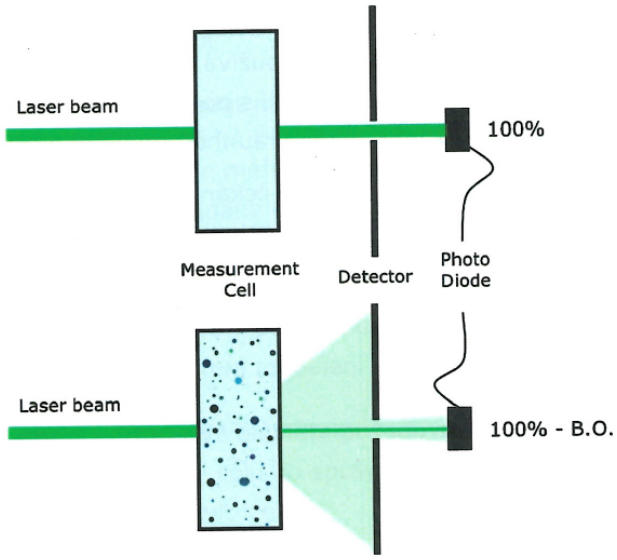

Figure 2. Concept of laser beam shielding

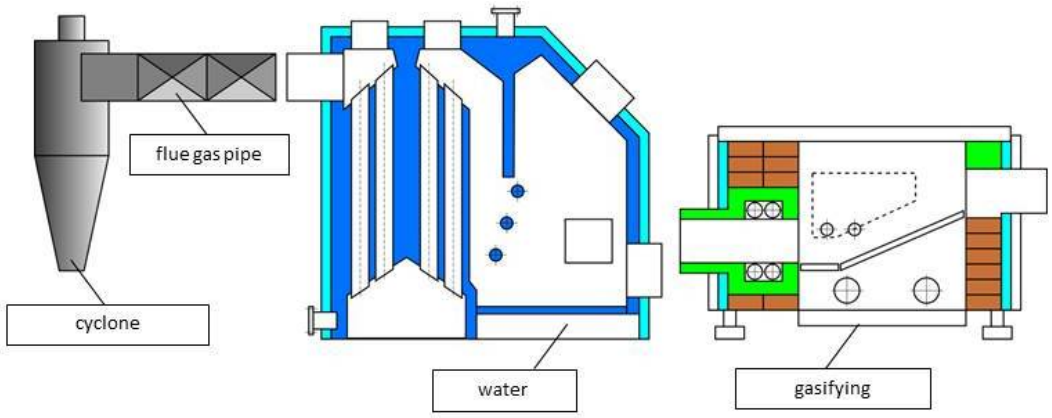

FIGURE 3. Diagram of the experimental device.

diffracted light then strikes a Fourier lens, in which a sensor (photodiode) measures the distribution of the intensity of the diffracted light in the focal plane in dependence on the angle of incidence. The sizes of the particles and their distribution are calculated on the basis of the sensor results. The concentration of the particles put into the device must be low enough to avoid multiple laser light diffractions. At the same time, the concentration must be high enough for the particles to be able to diffract enough laser light for the sensor to detect. The optimum shielding of the laser beam for wet dispersion is 10–15 % [2]. After an optimum sample amount is inserted into the device, the measuring will start automatically. Fig. 2 illustrates the principle of laser beam shielding. In the upper section, the laser beam is not shielded at all and the photodiode is struck with its full intensity. In the lower section, a sample is introduced and the intensity that strikes the photodiode has decreased due to the shielding of the laser beam caused by the introduced particles.

The device from which the samples were collected consists of a fuel feeder, a gasifying chamber, a water heater, an air preheater, an optional mobile oxygen separator and a cyclone separator. The water heater with nominal heat output of 110 kW was originally designed for combustion of solid fuels, and has been modified to combust syngas from the gasifying chamber. The gasification chamber [5, 6] is designed for combustion of loose wood, mostly wood chips and other similar biomass material. Sawdust and wood chips were used for the experiments. Figure 3 shows a diagram of the device with the extraction points highlighted.

3. Measument results

A total of four ash specimens were selected to undergo size analysis in the laser analyser. The laser analyser shows the results on data sheets, where the frequency of the corresponding range of particle sizes to the whole sample is displayed. All results are transparently arranged in the form of a diagram (frequency curve, cumulative or distribution curve, see Figure 4). The frequency curve represents the particle size distribution [4] related to particle volume. The cumulative distribution curve gives the percentage representation of particles in a sample of smaller size than the selected sample.

Figure 4 and Table 1 show the results of the ash analysis from the gasifying chamber. It can be seen from Figure 4 that the specimen contains a large proportion of big non-combusted particles. However, it also contains a significant amount of smaller particles. Thanks to the quality dispergation of the specimen in the water bath, even these small particles are detected, since they are not agglomerated. Agglomeration is typical for sieve analysis.

Figure 5 presents an analysis of a specimen that was taken from the water heater. It is a piece of ash that was carried by gas products from the gasifying chamber into the water heater. In comparison with the previous figure, it is evident that the number of large particles has decreased considerably and also that the number of particles smaller than 100 µm has increased.

Sample 3 was collected at a sampling spot located in the middle section of the flue gas pipe. The graph clearly shows that the measured sample contains only small particles. It is an essential prerequisite that necessary sedimentation occurs at larger particles along their way in that larger particles are sedimented as they pass through the flue gas pipe. The results are presented in Figure 6 and in Table 3.

The last sample was collected in the ash bin located at the end of the cyclone separator. The main functional parameters of a cyclone are separability and pressure loss. In general, the greater the pressure loss, the better the separability, but this may not always be the case. The particle size distribution of the gas admixture and the geometric configuration has the greatest influence on cyclone sereparability. When determining separability, we assume that:

- the particles are spherical in shape, and that their final speed is governed by Stokes' law;

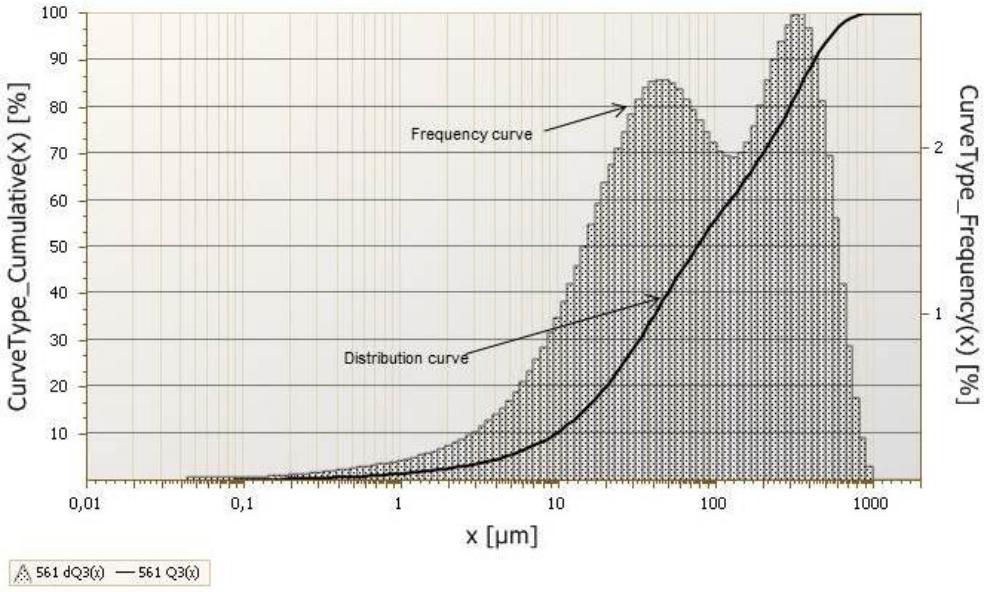

Figure 4. Results from the gasifying chamber.

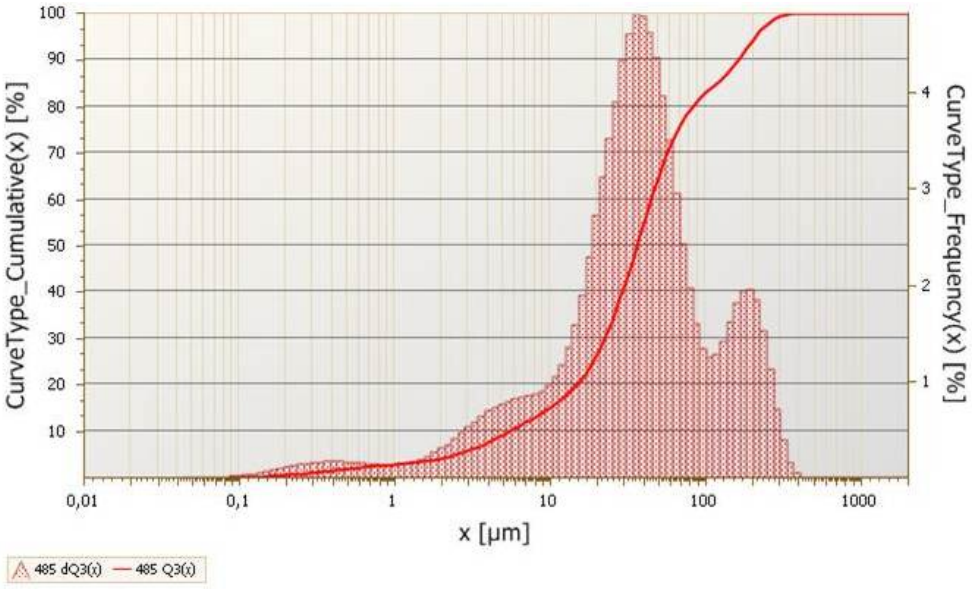

Figure 5. Results from the water heater.

x [µm]	y [%]
20	19.7
25	24
45	37.4
63	45.5
90	53.4
125	60
180	67.3
250	75.1
355	84.7
500	93.6
710	98.8
1000	100

Table 1. Results from the gasifying chamber.

x [µm]	y [%]
1	2.8
1.3	3.1
10	14.9
25	33.2
50	64.3
100	82.6
315	99.5
500	100

Table 2. Results from the water heater.

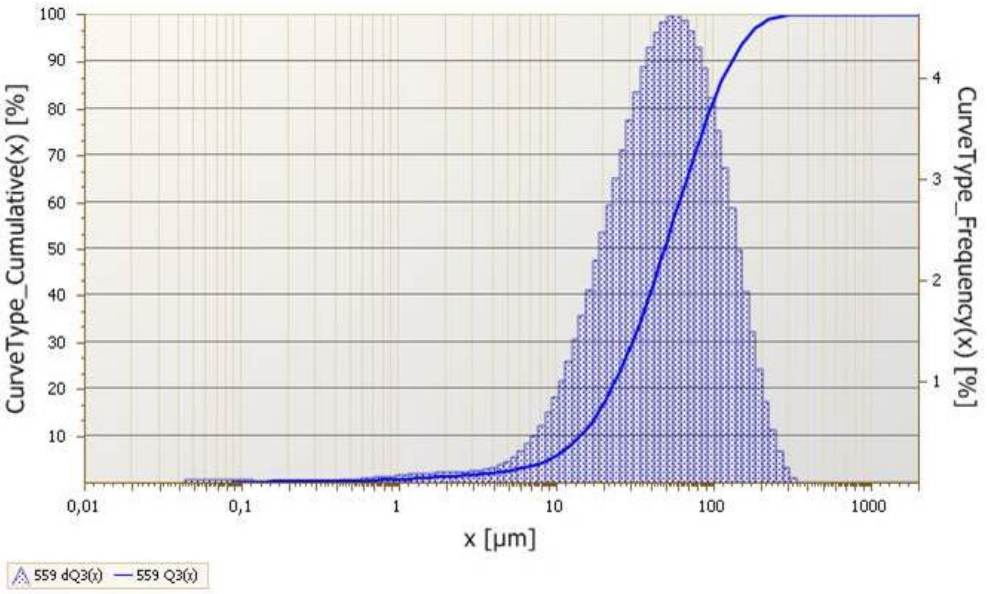

FIGURE 6. Results from flue gas pipe.

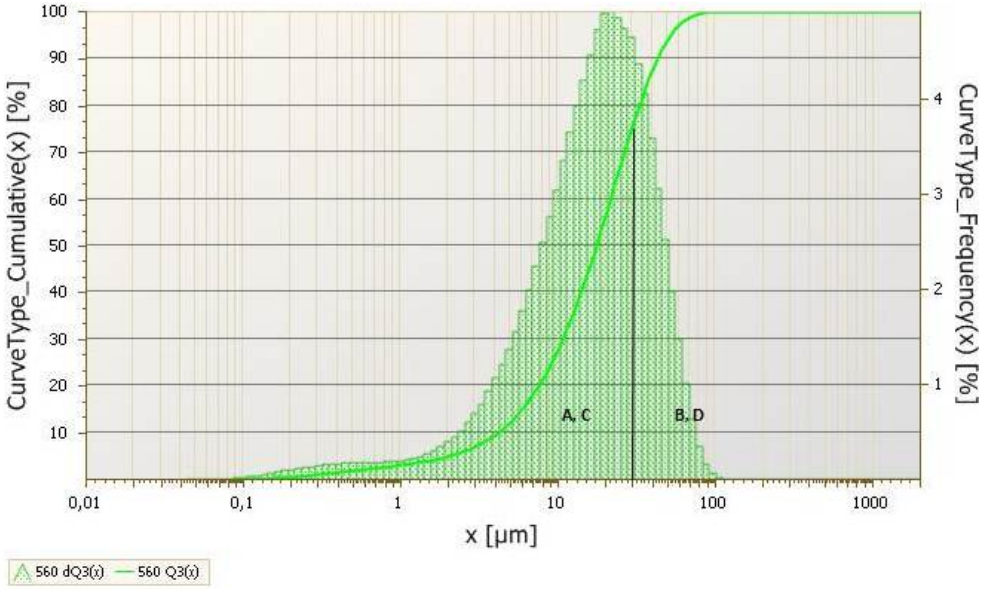

FIGURE 7. Results from the cyclone separator

x [µm]	y [%]
1	0.7
1.3	0.9
10	5.7
25	22.9
50	50.6
100	81.1
315	100
500	100

TABLE 3. Results from flue gas pipe.

x [µm]	y [%]
0.1	0
2.5	5.7
4	9.3
8	20.9
15	42.1
30	75
55	95.8
100	100

TABLE 4. Results from the cyclone separator.

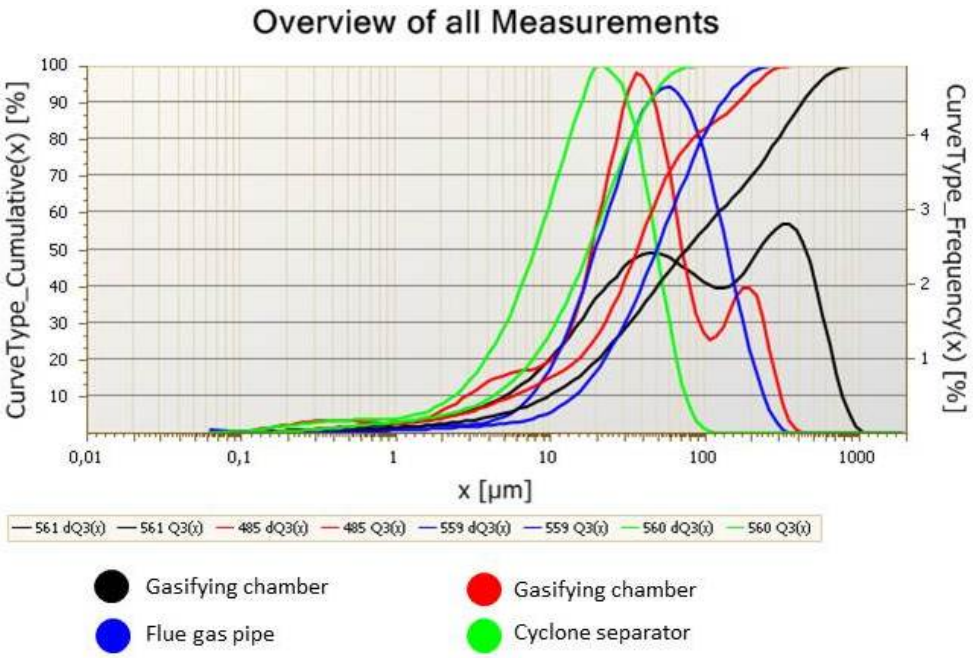

Figure 8. Overview of all measurements.

	Frequency portions		Weight portions	
[µm]	A [%]	B [%]	C [%]	D [%]
30	75	25	13.15	86.85

Table 5. Frequency and weight portions.

- the concentration and the particle fall speed are even in the cyclone input section;
- the particles do not interfere with each other, i.e. they do not gather or break away
- no turbulence or secondary flow occurs.

Our experience with calculations and the assumptions stated above imply that particle separability of 30 µm can be provided by this cyclone. Figure 8 states the percentage results for 30 µm. Labels A and B stand for the percentage frequency ratios, and areas C and D mark the percentage weight ratios. For conversion to a weight ratio (C, D), it was considered that all particles are spherical in shape, with density $\rho = 1200\,\mathrm{kg/m^3}$. The results show that particles larger than 30 µm are the main weight carrier, despite the fact that their frequency in the measured sample is significantly lower than that of particles smaller than 30 µm. All this is shown in Figure 7 and Table 4. Particles leaving the device for the atmosphere will be analysed in a future extension of our research.

4. Conclusions

This paper has presented a detailed analysis of ash specimens extracted from biomass combustion. The modern laser diffraction method that was used for the analysis fully replaces previous methods, such as sedimentation and particle-size analysis. The major advantage of this method concerns particle detection in a water environment, where quality and sufficient dispergation occurs what does this mean? The goal was to show the size spectrum of particles taken from each sampling spot in the device. Our evaluation of these samples shows the decrease in the size of the particles as they travel through the whole device. The largest particles are captured right at the beginning, when the fuel is being gasified. Afterwards the particles gradually sediment as they travel through the device. Figure 8 presents a comparison of all measurement results, in which the differences in particle size are clearly visible.

Acknowledgements

The work presented in this paper has been supported by the European Regional Development Fund in the framework of the NETME Centre research project within the Research and Development for Innovation Operational Programme.

Our work has also received financial support from the Brno University of Technology under the grant FSI-J-13-2090.

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